Plants in Lunar Exploration - Scalable assays of complex biology and life support

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HMP

NLSC 2008

Life Support Adjuncts and Habitation

- Plants complete the habitation environment
  - Water
  - Oxygen
  - Food and fiber
- Sustained presence in human migrations
  - Historical precedent
  - Selections and engineering for locale
  - Robust biological systems
  - Gather and modify in situ resources

Plants as Biological reporters

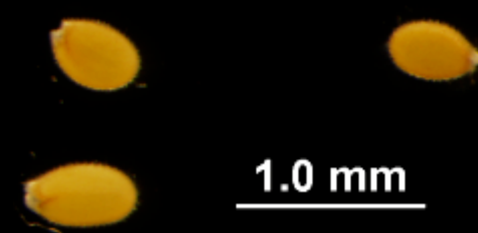
- Plants are complex, higher eukaryotic organisms:
  - Many basic cellular and metabolic process are the same in plants as in humans, mice, flies, worms etc
  - Start from embryo, meristems undifferentiated cells
  - Subject to environmental stresses: radiation, UV, atmospheric changes, gravity, temperature

- Yet unlike animals…
  - Can be transported in a dormant state for decades
  - Evolved to adapt to environment in situ
  - Well suited for genetic and metabolic engineering
  - Require minimal life support and resources

Arabidopsis: an ideal plant reporter -scalability

- Very small, rapid life cycle, small genome
- Long history of research and development, spaceflight
- Genome sequenced, can be readily engineered with virtually any gene of interest, rich datasets

One arabidopsis seed has a mass of ca. 0.0175 mg – or about 57,000 per gram



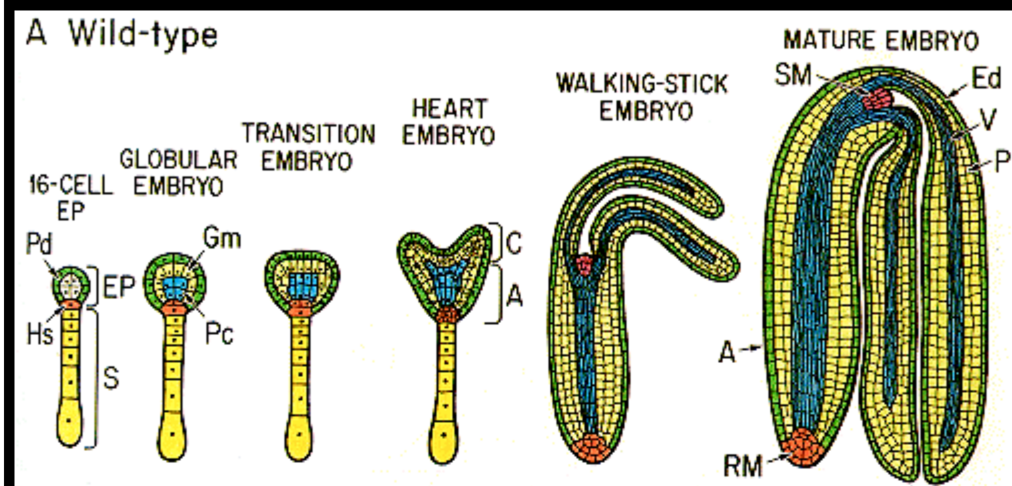
Arabidopsis development

Scales time, dimension and complexity
Environment sensorium

1 day

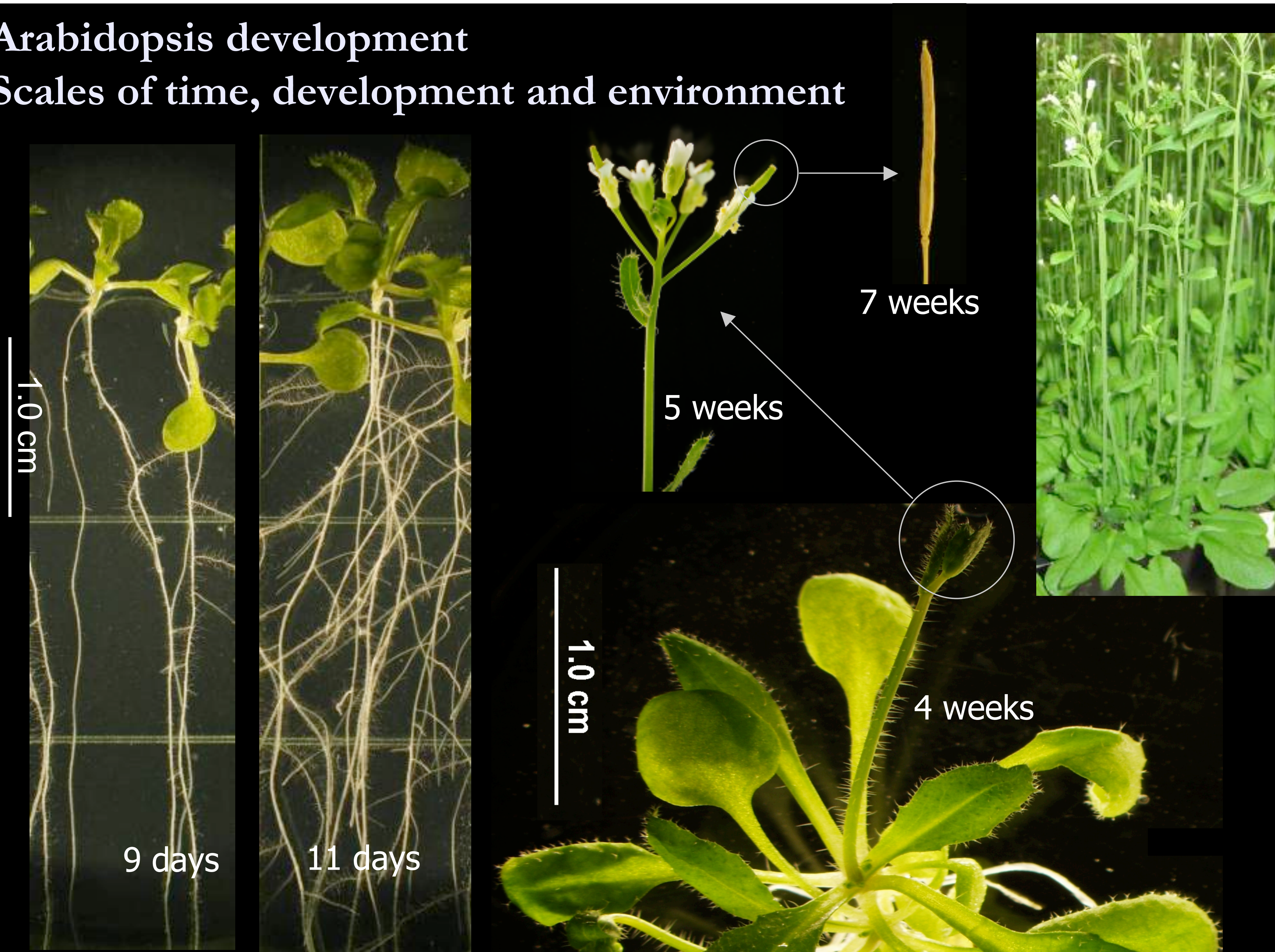
2 days

3 days

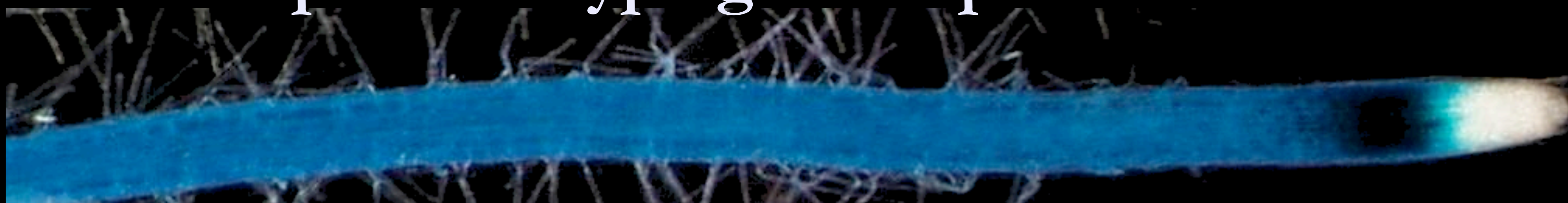


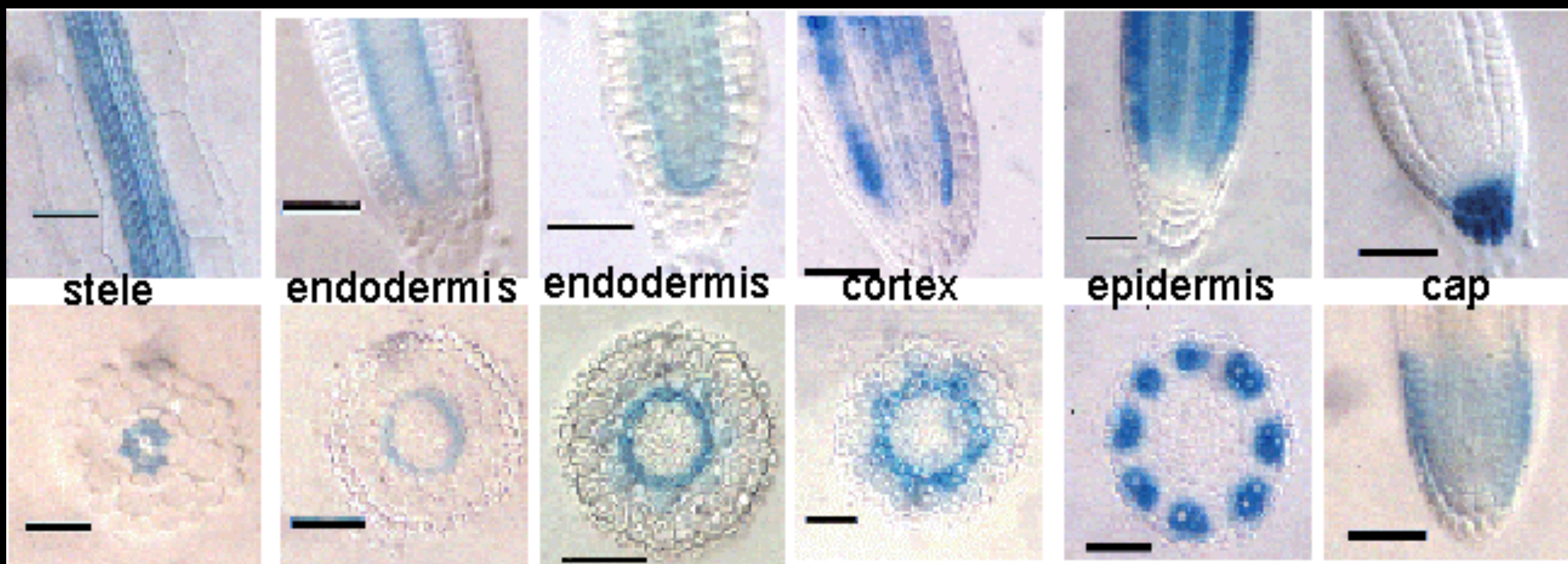
Yadegari, et al. (1994) Plant Cell 6:1713-1729.

Arabidopsis development
Scales of time, development and environment



Arabidopsis cell type gene expression

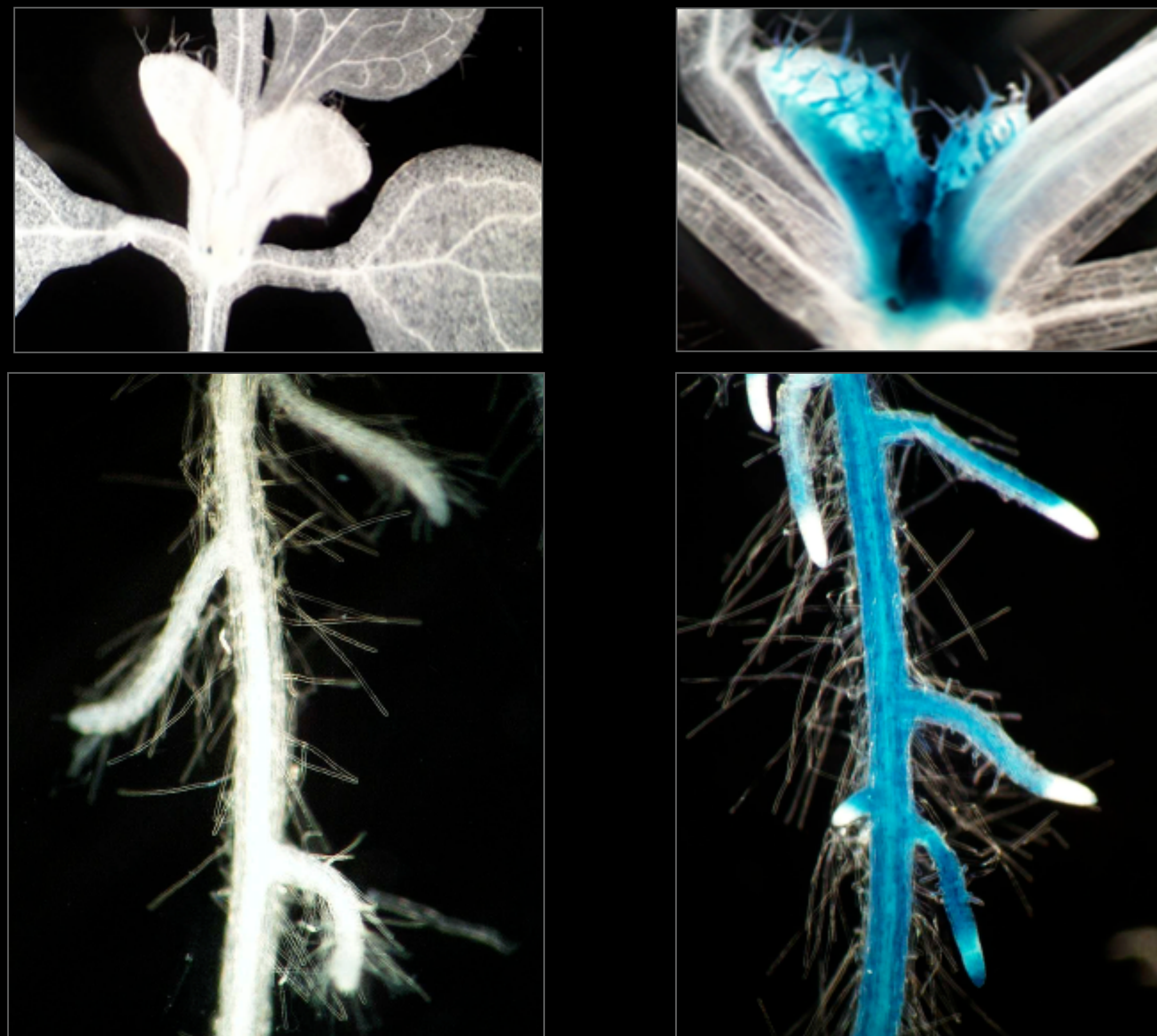




Specific cell types in these roots were marked by “enhancer trapping” which allow the visual identification of cell types based on developmental or functional distinctions from their neighbors.

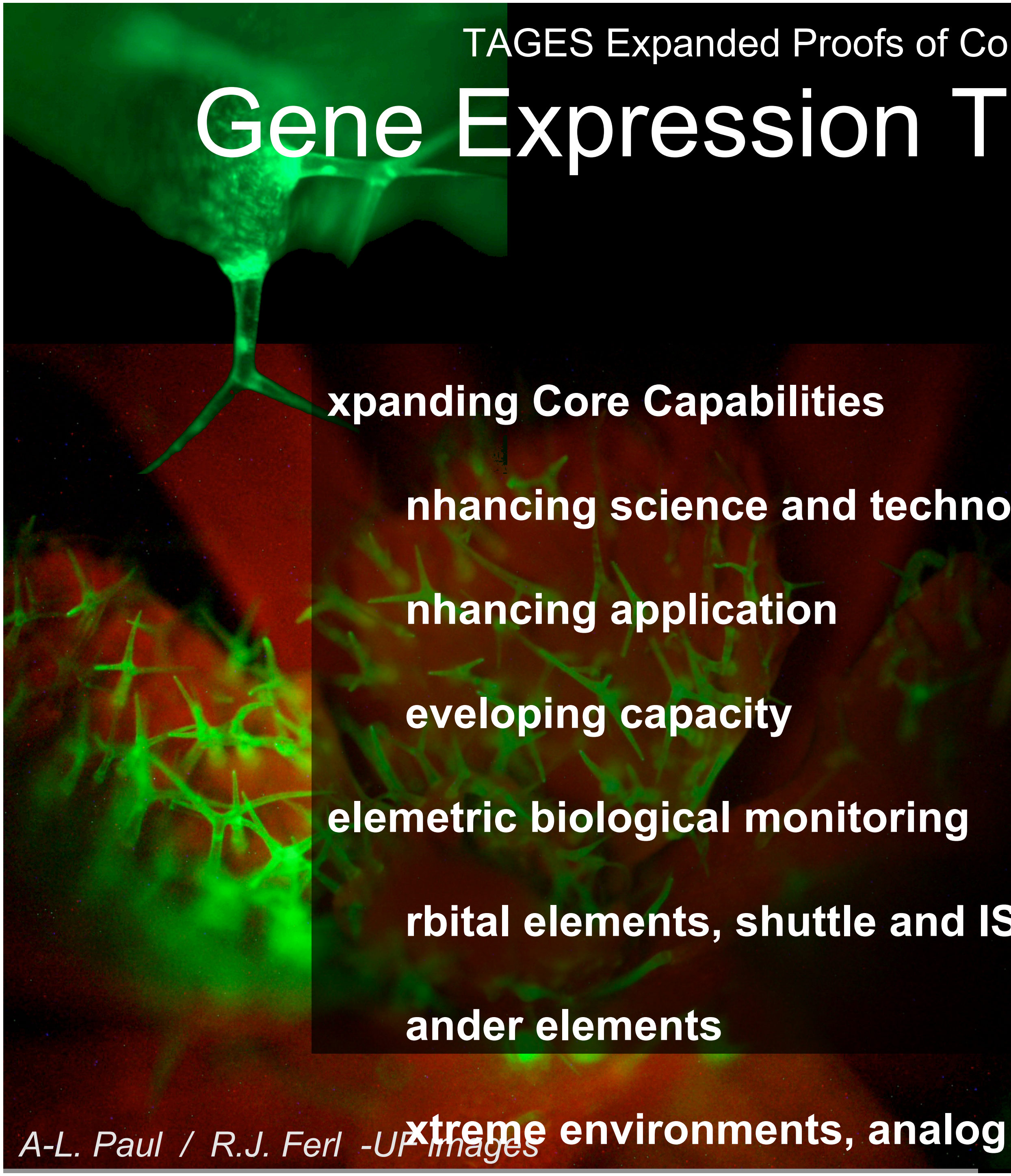
After: Malamy, J. and Benfey P. (1997) Organization and cell differentiation in lateral roots of Arabidopsis thaliana. Development 124: 33-44.

Highly attuned environment sensorium



TAGES Expanded Proofs of Concept

Gene Expression Telemetry



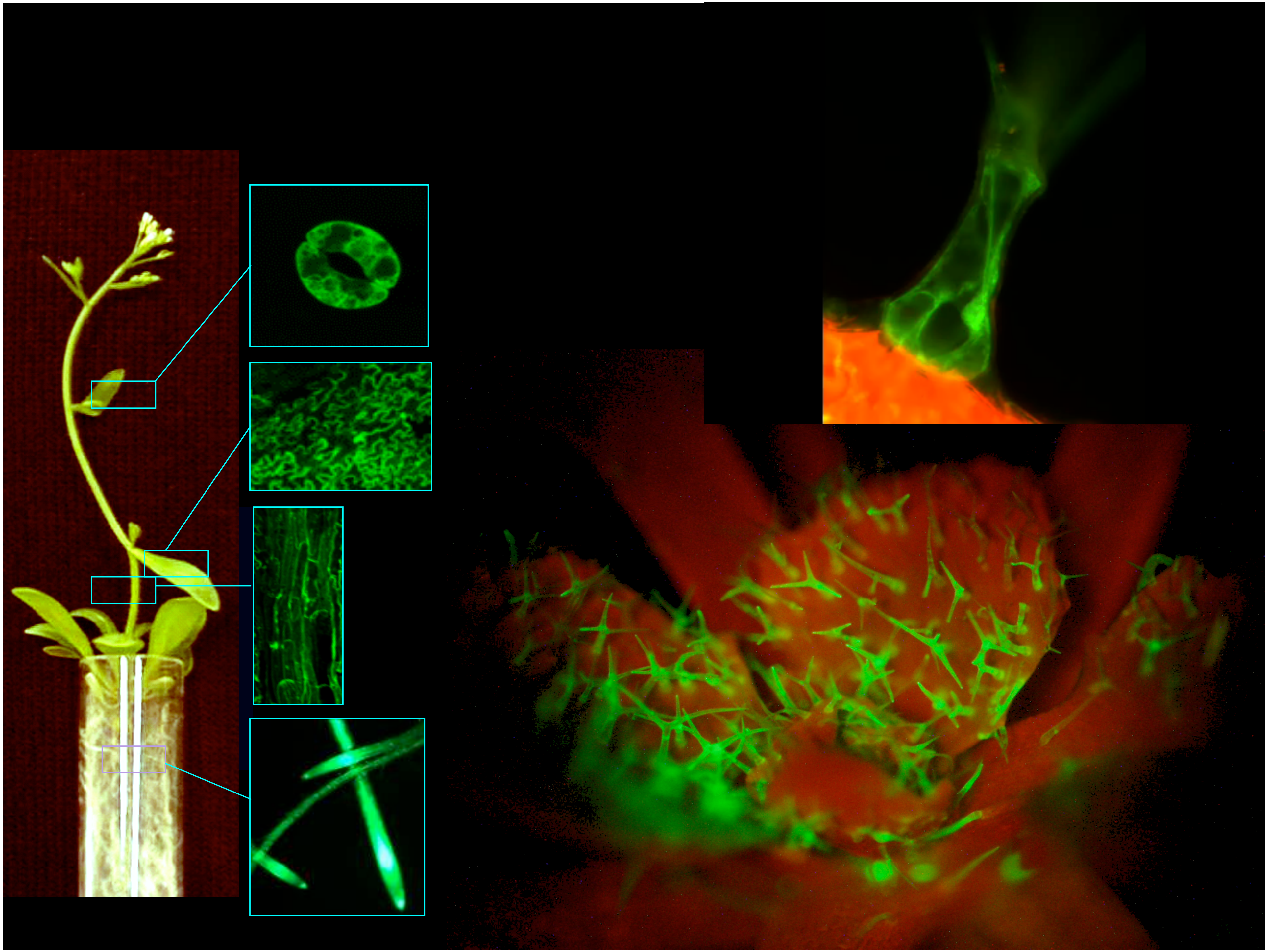
xpanding Core Capabilities

- **nhancing science and technology development**
- **nhancing application**
- **eveloping capacity**

elemetric biological monitoring

- **rbital elements, shuttle and ISS heritage, genesat**
- **ander elements**
- **xtreme environments, analog environments**

A-L. Paul / R.J. Ferl -UF images



- Plants cope with stress by adaptation in situ, no avoidance
- Plants lend themselves well to metabolic and genetic engineering, especially for reporter genes
- Genes as indicators of in situ responses
- Plants are integral part of sustainable life support systems
  - Habitation
  - Advanced ecology systems

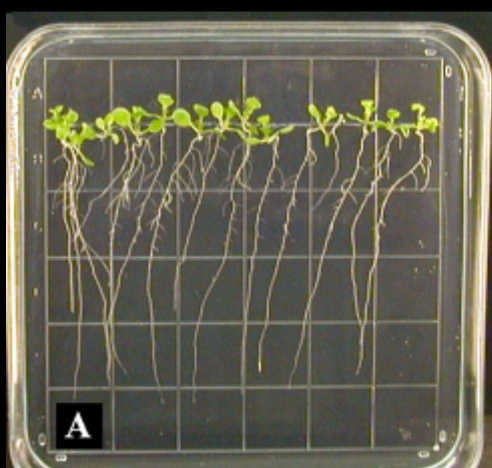
Human Spaceflight Heritage
Plants / Arabidopsis

- Biostack – Apollo > Gemini
- Moon Trees – Apollo 14
- Skylab
- Shuttle
- Mir
- ISS

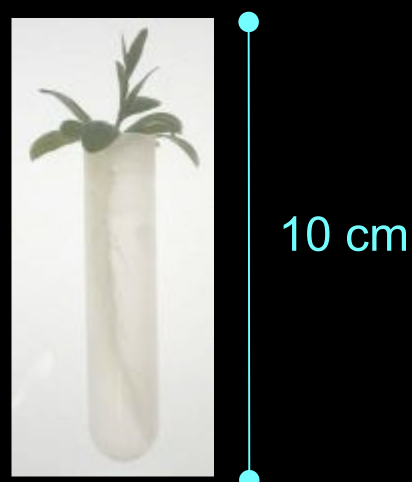
Plant
Growth
Chamber

Spaceflight Heritage

- TAGES on STS-93 KSC Dynamac Bionetics
  - Spaceflight induced changes in gene activity
- APEX TAGES 2JA
  - Spaceflight telemetric gene expression



9 day old plants - vertical plate

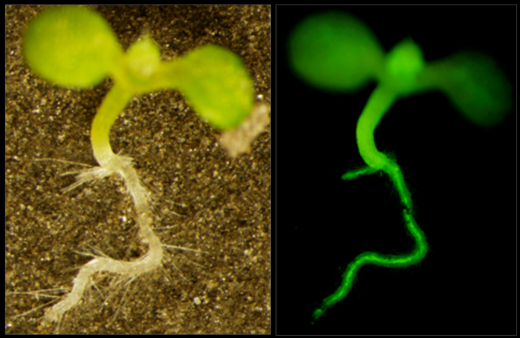


21 day old plant - 9mm tube

Spaceflight Heritage

- Hardware, smaller scale
- Procedures
- Science
- Life support, larger scale

Analog Heritage



- Contained agriculture
- Limits of terrestrial growth
- Lunar simulants and impact breccia

Plant
Growth
Chamber

Scalability; early discovery phase

- Minimal
  - <5 watts, 2-5 kg
  - <14 days
  - Science
    - Germination, growth, development, exposure, gravity
    - Gene expression
    - Little or no ISRU
- Nominal-Maximal
  - 5-10 watts, 3-10 kg
  - 30-45 days
  - Science
    - Germination, growth development, generational, exposure, gravity
    - Gene expression
    - ISRU – regolith, light, other
    - Leave behind, future collection; seeds

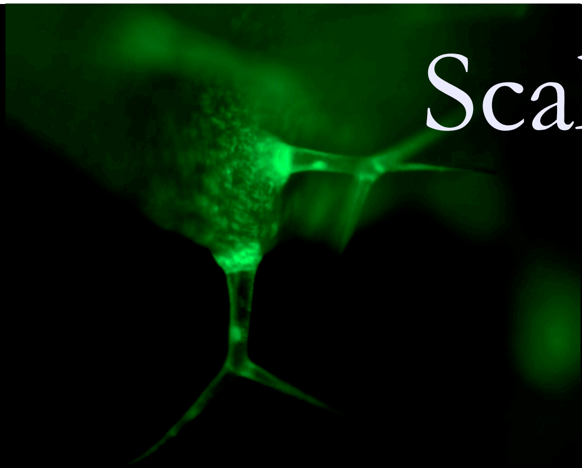
Plant
Growth
Chamber

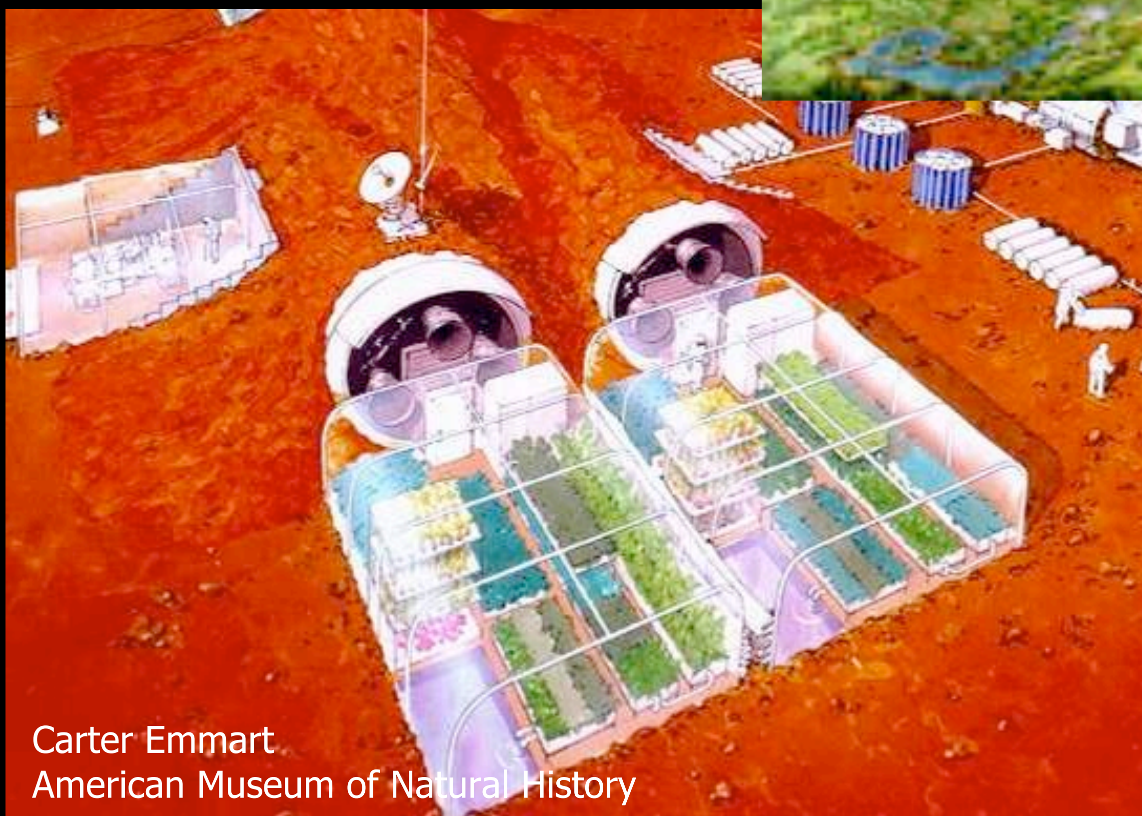
Scalability; production phase

- Habitat adjunct, resource recovery, food air water
  - Lighting
  - Closure parameters
  - Science
    - Plant modification
    - Gene expression
    - ISRU
- Full deployment
  - Production facility
  - Support parameters
  - Science
    - Pressure ranges
    - Plant modifications
    - Nutrition, O2 and H2O return

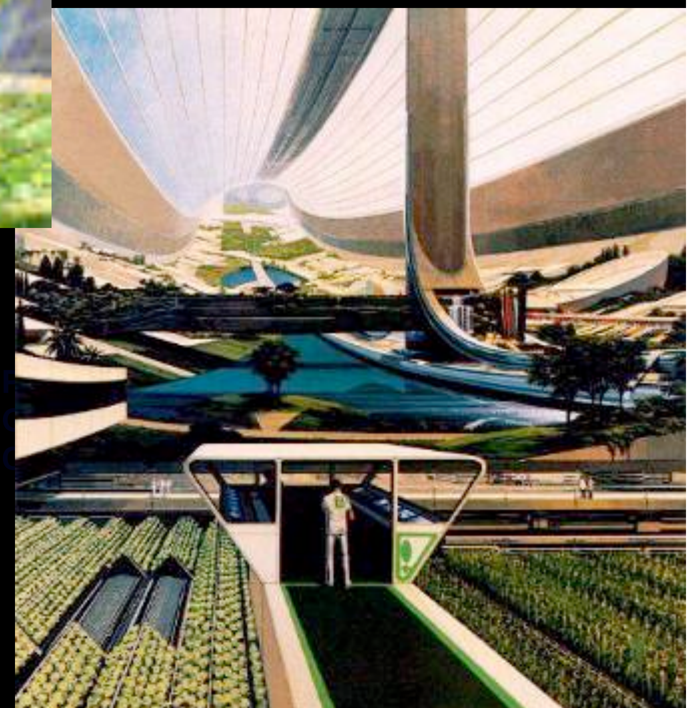
Plant
Growth
Chamber

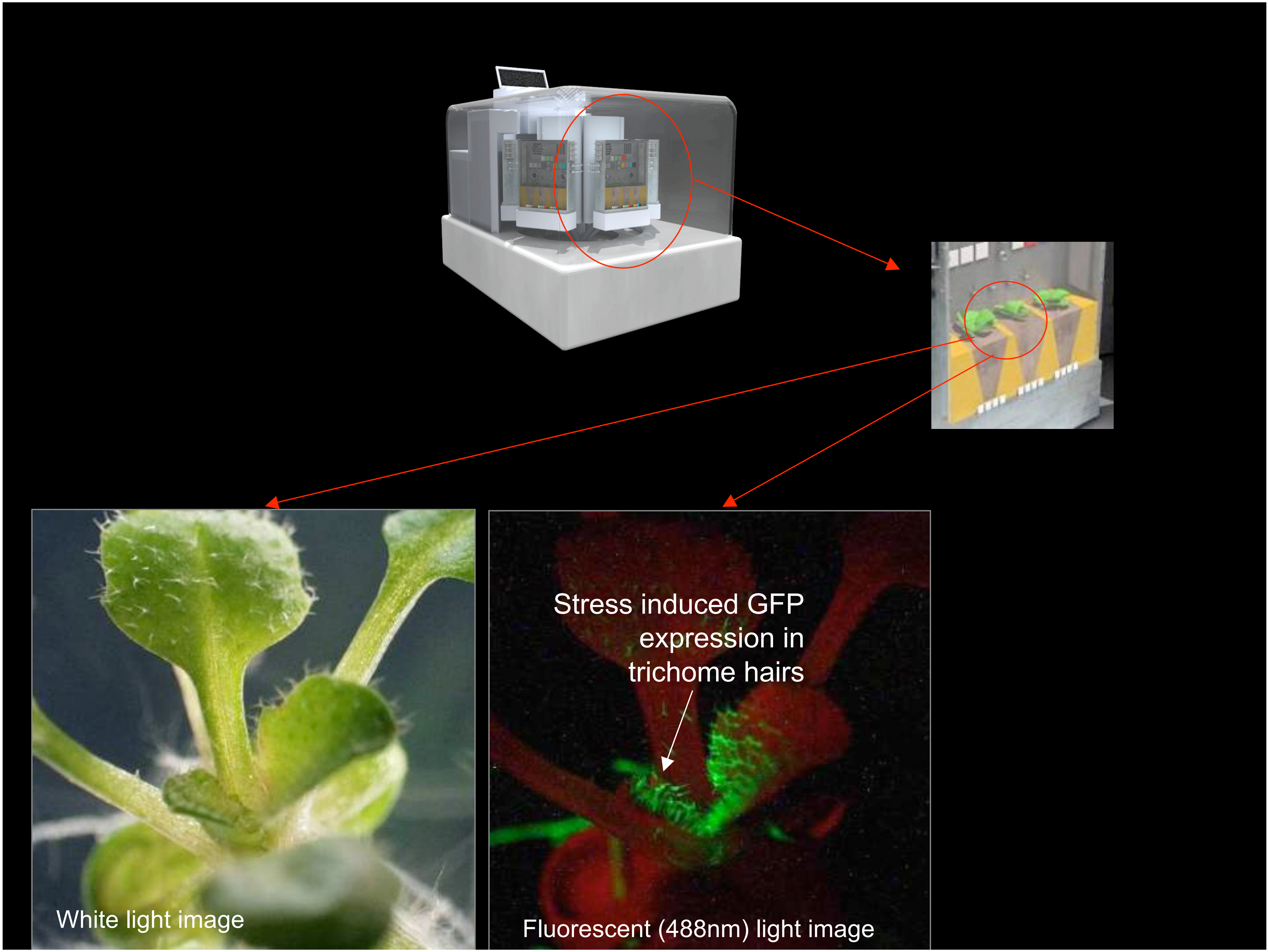
Scalability – long term





Carter Emmart
American Museum of Natural History




Stress induced GFP
expression in
trichome hairs
White light image
Fluorescent (488nm) light image

- UF Biotechnology
  - Anna-Lisa Paul
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- UF Architecture
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- Guelph University
  - Mike Dixon
  - Tom Graham
- HMP
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